Signature of X-ray Line Formation of Fe XVII by Charge Exchange

Completed Technology Project (2016 - 2019)

Project Introduction

Fe XVII dominates the spectral emission of a large number of astrophysical X-ray sources and, thus, is of prime diagnostic importance, as illustrated in numerous measurements by Chandra and XMM-Newton. Although immense progress has been made in laboratory measurements and spectral calculations of collisional plasmas since the launch of these X-ray observatories, model calculations of the Fe XVII X-ray spectrum still do not yield agreement with laboratory measurements or astrophysical observations that is completely satisfactory. Charge exchange is another line formation mechanism that can produce Fe XVII X-ray emission. However, line formation by charge exchange is ill understood, even in the case of 'simple' K-shell spectra of hydrogenlike or heliumlike ions. Nevertheless, simple spectral markers have been developed that represent proof for the presence of charge exchange even if the details of line formation are not yet fully clear. By contrast, there are essentially no charge exchange measurements and calculations for the much more complex Fe XVII L-shell X-ray spectrum. Whether charge exchange contributes an observable amount to X-ray line formation in astrophysical situations is controversial, as (arguably) no incontrovertible spectral evidence for charge exchange has been presented from sources outside our own solar system. In part, this is due to the fact that charge exchange is a mechanism that requires an extended source to be effective, such as circum-stellar halos or super nova remnants expanding into surrounding space, and so far there have been no measurements of extended sources with high spectral resolution. In addition, laboratory measurements have not yet provided data that could serve as spectral markers for charge exchange in the Fe XVII spectrum or, for that matter, in the other L-shell X-ray emission spectra of iron, i.e., Fe XVIII through Fe XXIV. As a result, it is not yet possible to argue that an observed iron L-shell X-ray spectrum is produced fully or in part by charge exchange. The impending launch of Astro-H with its X-ray microcalorimeter instrument will change the way we will study the X-ray emission from extended sources. For the first time, we will have the spectral resolution to see individual X-ray lines from diffuse objects, and it will become possible to discern contributions from charge exchange, or, at least, put limits on the contributions of this process to the overall line formation. In order to exploit the new capability afforded by the microcalorimeter on Astro-H and to firm up the diagnostic significance of the emission from Fe XVII and of the other L-shell iron ions, we propose to conduct a set of laboratory astrophysics experiments to identify the signature of L-shell X-ray line formation by charge exchange. The experimental effort will focus on Fe XVII, but it will also study charge exchange produced emission from Fe XVIII - Fe XXIV in order to cover a wide range of plasma temperatures. It will utilize the Livermore electron beam ion trap (EBIT) and the EBIT Calorimeter Spectrometer (ECS), which resides at the facility and has the same performance specifications as those of the microcalorimeter aboard Astro-H. In addition, we will make the first modeling calculations of charge exchange produced X-ray emission of L-shell iron using a simple model we had developed earlier for studying K-shell X rays. Our

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Astrophysics Research and Analysis

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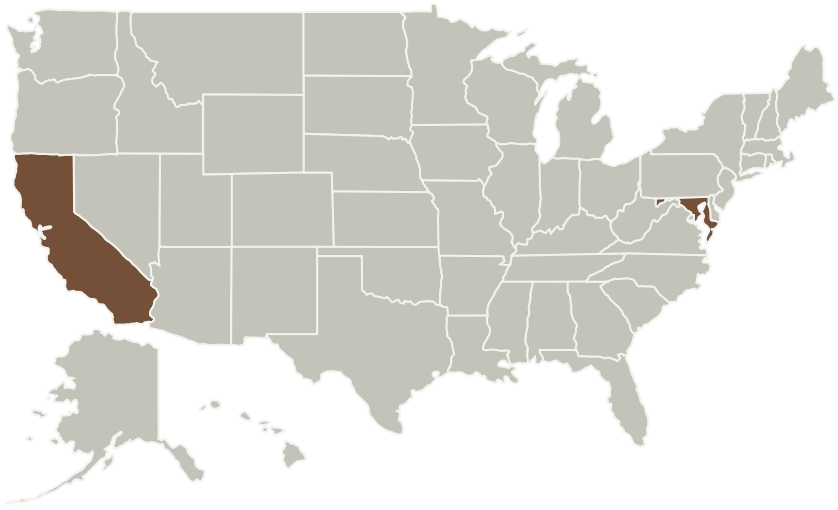
laboratory work will, thus, provide the tools needed to identify and quantify charge exchange as a line formation mechanism in extended astrophysical objects.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Department of Energy(DoE)	Supporting Organization	US Government	Washington, District of Columbia

Primary U.S. Work Locations	
California	Maryland

Project Management

Program Director:

Michael A Garcia

Program Manager:

Dominic J Benford

Principal Investigator:

Peter Beiersdorfer

Co-Investigators:

Frederick S Porter
Scott W Tyler
Gregory V Brown
Vola M Andrianarijaona
Caroline A Kilbourne
Maurice A Leutenegger
Richard L Kelley

Technology Areas

Primary:

- TX01 Propulsion Systems
  - TX01.2 Electric Space Propulsion
    - TX01.2.3 Electromagnetic

Target Destination

Outside the Solar System